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DESIGNING THE MATHEMATICS CLASSROOM.

BY- BARTNICK, LAWRENCE P.
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IN ORDER TO PROVIDE INFORMATION ON PLANNING A MATHEMATICS CLASSROOM TO MEET THE NEEDS OF A MODERN EDUCATIONAL PROGRAM, THIS BOOKLET PRESENTS DISCUSSIONS OF (1) PHYSICAL FEATURES OF A MATHEMATICS CLASSROOM, (2) FURNISHINGS, (3) EQUIPMENT, AND (4) FLOOR PLANS. A BIBLIOGRAPHY ON THE SUBJECT IS PROVIDED. (JT)

Designing the *Mathematics Classroom*

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Lawrence P. Bartnick

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NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS

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Designing the

Mathematics Classroom

Lawrence P. Bartnick
High School
Natick, Massachusetts

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I. Introduction

Why This Booklet Was Written

Mathematics classrooms of the past (and unfortunately many of the future may be the same) were no different from those built for other subject areas. In fact, many mathematics teachers find themselves changing rooms as much as four to five times a day to teach a subject that should have an environment all its own. Working under conditions of this type is a distinct handicap to both teacher and student. The teacher can do little more than expose the student to the content of the text, and with the student it unfortunately becomes a case of "sink or swim." Nevertheless, a great number of enrichment activities can take place in a mathematics classroom that have a natural attraction to the student, and that diversify learning experiences to the extent that even the student with the lowest I.Q. is bound to learn something. However, a program of this type cannot be operated in the typical classroom of the past; instead, specialized rooms are needed, rooms that will be used exclusively for the teaching of mathematics. The pages that follow will present suggestions with regard to type, size, and content of the mathematics classroom that will best serve the needs of a modern educational program.

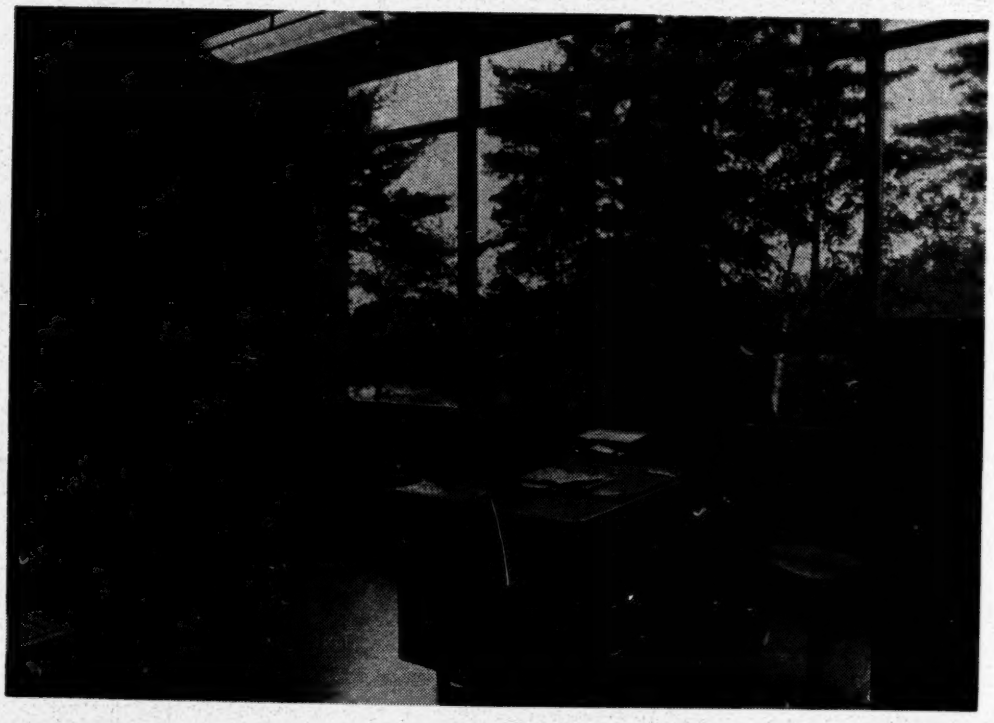
A further need for a booklet of this kind is indicated by the lack of singularly thorough sources for planning mathematics classrooms. Of course, there are a number of excellent articles[1] from which one may derive many useful ideas, but the majority are either too general in scope or cover only a few of the facets of the entire problem. Studies are needed to coordinate the content of these articles in order to provide single comprehensive sources from which teachers can get all the information they desire pertaining to the design of modern mathematics classrooms. Such sources will be more economical of the teacher's time and, as a result, may provide an additional incentive to encourage teachers to participate more in layout planning. It is hoped that this study will be a step in that direction.

Errors of the Past

If one were to visit a number of more recently built high schools, it would be discouraging to note that, in general, the only distinguishing characteristics between mathematics classrooms and other classrooms are sections of scored chalkboards. Most of the teachers, if asked, would probably indicate they had little or no part in the preliminary stages of planning. In fact, the majority of teachers would be compelled to admit that layout planning was done almost exclusively by the architect.

[1] See bibliography.

Classrooms erected under these circumstances probably are as structurally sound as any other, but they lack a certain distinctiveness which allies them to the particular field of mathematics for which they were intended. It must be remembered that the technical knowledge of an architect, although of primary importance, is not the only criterion for proper design of mathematics classrooms. Architects are not necessarily aware of the multitude of activities that will take place in the classroom; of the various project materials and pieces of equipment



that must be stored; of the chalkboard-tackboard ratio desirable to a group of mathematics teachers, and the like. These problems, however, have a direct bearing on the many facets of classroom design and can best be provided for by the mathematics teacher himself.

So it seems that classroom planning is a group venture in which the mathematics teacher can make a definite contribution. Results of such planning will mean a more functional classroom and eventually a vastly enriched mathematics curriculum.

II. Physical Features of a Mathematics Classroom

Size of Room

In the past it has been subjectively determined that high school classes of more than 35 pupils were unsatisfactory. It was also felt that space required per pupil should not be less than 18 square feet. Many state departments have specified that the width of the room shall not be more than twice the height for lighting purposes. The result of combining these standards was a typical classroom approximately 22 feet by 29 feet with variations of one to three feet in either dimension. Obviously, mere dimensional requirements are not satisfactory bases for planning.

It is interesting to note that in 1942 Engelhardt and Leps (14)[1] recommended a recitation room 24 by 40 feet plus a workroom 10½ by 24 feet. However in 1949 the same Engelhardt, and others, (15:100) made the following observation:

> A standard class size has been a major determinant of the spaces provided in many schoolhouses. Class size may vary more in the future than it has in the past. The emphasis upon individual activity and expression, the possibility of teaching some phases of the curriculum with larger groups of students, the proven success of the talking picture for instructional purposes with large groups, and the wider freedom of the classroom should be given greater consideration in the planning of room sizes than the more dimensional requirements which unwisely have been incorporated in law.

Thus it is evident that the activities which are carried on in the modern classroom must be known to the architect before he can plan. Room size cannot be arbitrarily fixed. It must be the result of many discussions.

The *Architectural Record* (1, 2) presents a good summary regarding room size. Table 1 and Table 2 which follow, adopted in part from this publication, give the statistical details regarding "recitation-discussion" rooms and "discussion-activity" rooms. The former provides area for seating, storage, and a reading alcove, and although it is more adequate than many of our present classrooms, it still does not provide space for all of the activities that should take place in modern pedagogy. The second type of room provides area for seating, storage, a workroom, and a reading alcove, and seems better adapted to meet the needs of modern teaching procedures. The "discussion-activity" room data may be applied to the mathematics laboratory which is mentioned by so many authors in literature of the past two decades.

Desirable width and height for classrooms and workrooms are difficult to limit because they are affected by such factors as air distribu-

[1] In this pamphlet the symbol (x:y) will be used to refer to page y of reference x in the numbered bibliography at the end of the pamphlet.

tion patterns, solar angle, horizontal exposure, and the like. It suffices to say that typical width ranges run anywhere from 22 to 25 feet and, in general, ceiling heights are becoming lower. The latter trend is particularly noticeable in campus type high schools which are becoming so popular in modern design.

TABLE 1

AREA REQUIREMENTS FOR RECITATION-DISCUSSION PROGRAM

Spaces	Acceptable minimum	Average	Usual maximum
1	2	3	4
Classroom			
Total area (square feet)	660	704	770
Pupils (per room)	20–25	30	40
Area (per pupil)[a]	22	23	26
Auxiliary spaces			
Storage (cubic feet)	125	170	250
Bookshelves (linear feet)	30	50	60
Reading alcove (square feet)	64	100	176

[a] Legal minimum area in many states is 15 to 16 square feet per pupil.

TABLE 2

AREA REQUIREMENTS FOR DISCUSSION-ACTIVITY PROGRAM

Spaces	Acceptable minimum	Average	Usual maximum
1	2	3	4
Classroom			
Total area (square feet)	704	828	1200
Pupils (per room)	20–25	30	35–40
Area (per pupil)[a]	23	28	40
Auxiliary spaces			
Workroom (square feet)	176	230	360
Teacher's office (square feet)	100	100	150
Book shelves (linear feet)	40	55	70
Storage (cubic feet)	200	320	400
Reading alcove (square feet)	64	100	176

[a] Legal minimum area in many states is 15 to 16 square feet per pupil.

Wall and Ceiling Materials

The important factors involved in wall and ceiling decorations are cheerful effects, ease of cleaning, and high light reflection. The best material for walls is plaster but they may also be surfaced with plywood or faced with tile. Interior wood finishes should be covered with a light, clear varnish. Gloss varnishes or dark stains are to be avoided. The ceiling may be covered with acoustical plaster or tile; however, plain plaster has also been used successfully in many schools. For large classrooms acoustical materials of some kind seem a necessity but it must be remembered that acoustical plaster loses its efficiency after a short period of time and should be used in a limited degree. Colors should be used to give the widest possible diffusion of light and to wipe out dark spots in rooms. The scheme must be thought of as inclusive, applying to walls and ceilings. The use of almost any tint is practical with blue, blue-greens, and greens particularly valuable in reducing eyestrain. Psychology dictates that warm colors are effective on northern exposures and cool shades on southern exposures. The harmonious use of color tends to provide warmth and cheerfulness and to encourage pride and respect for school property. If paint is used on a ceiling, it should have a light reflecting value of at least 75 per cent. Wall paints should be nonglossy, flat, or mat type with at least 60 per cent light reflecting value. Surfaces below eye level and working surfaces should have a light reflecting value of approximately 30 per cent.

Doors leading to a corridor are often glass-paneled with a transom above. Modern systems for lighting and ventilation may make a transom unnecessary. A glass panel and transom are not needed for doors connecting rooms. A transom, if used, should be so constructed that entrance into the room through the transom is difficult if not impossible. The width most often used for doors is 3 feet 1 inch. If masses of students change rooms each hour, it will be found desirable to plan two corridor doors to each classroom. In some states the minimum number of doors required from room to corridor is controlled by state law.

The preceding paragraphs are adapted from suggestions made by the Department of Education of West Virginia (12:29-38), N. L. Engelhardt and others (15:209-11), and J. W. Ramsey (34).

Floor Covering

Selection of floor covering must be made with the following factors in mind: durability, light reflection, economy, safety, resilience and quietness, cleanliness and sanitation, ease of repair, and color. There are a number of products on the market that seem to meet all requirements and have proven to be successful. However, those most frequently used are battleship linoleum, rubber tile, and asphalt tile. Hardwood floors also continue to maintain popularity, but tend to be noisy and more difficult to clean with age. If wood flooring is used, all movable

furniture should be equipped with glides which are silenced with rubber inserts. If acids or other chemicals are to be used in conjunction with a mathematics laboratory course, the flooring must be acid resistant. Dustproof concrete or terrazzo is recommended in this case (12).

Heating and Ventilation

The most comprehensive statewide study of heating and ventilation was undertaken in New York State through the joint efforts of the Division of School Buildings and Grounds and the Division of Research of the New York State Education Department (29). They state in part:

> Capacity of the heating plant should be figured after studying the past weather experience of the locality. Extreme low temperatures over past years should be considered, tempered by judgment as to the severity of exposure to cold winds offered by the site and as to structural materials and insulation to be used in the building. . . . Reserve heating capacity should be provided for "pickup" and pipe losses. Additional capacity for future extension of the building should be considered carefully.
>
> A part of the heating system present in the classroom, often not clearly recognized as such, is the congregation of heat-producing human bodies. During the mild weather or periods of high solar heat input through the windows, the human heat liberated, alone, or combined with sun heat, often exceeds that escaping from the classroom through the structure; so that cooling may be needed even after the installed heating system has been turned off either by hand or automatic control.
>
> . . . referring to the discussion of physiological principles governing heat exchange between the body and its environment, it may be stated that those heating systems which transfer more of their heat input to the room by radiation than by convection are more likely to produce superior sensations of comfort.

The committee engaged in this study concluded that the essential objectives as outlined above could be derived from any of the following: (a) direct heating with window air supply and gravity exhaust, (b) direct heating with window air supply and duct exhaust with central fans, (c) direct heating with forced unit ventilator air supply and corridor gravity exhaust, (d) forced warm air with central or zone fans, or (e) panel heating with window air supply and duct exhaust by gravity or central fans.

Essex (16:60) believes that heating and ventilation equipment should be designed and installed to achieve two purposes. First, a proper thermal environment should be provided in the classroom; that is, the room should be held at an even, satisfactory temperature. Second, odors and toxic substances should be eliminated from the atmosphere. The three common types of ventilating systems in use, according to Essex, are: (a) open window system with gravity or forced exhaust, (b) unit ventilator, and (c) central fan with exposure zoning.

It should be noted that air disinfection and radiant or panel heating are in the experimental stage and may prove satisfactory for classroom use. At the present time, no classroom heating and ventilation system has proved entirely satisfactory. All seem to be too expensive, noisy, or inefficient.

Lighting

Essex (16:60-61) presents an excellent summary of the trends in schoolhouse lighting. There seems to be four trends in school plant lighting, two of which conflict with each other. . . .

1. . . . A tentative report of the School Lighting Committee of the Illuminating Engineering Society suggests 40 footcandles. Some authorities speak of from 50 to 100 footcandles. Fluorescent lighting has greatly encouraged the higher levels.
2. Increasing attention to the "company the footcandles keep." A classroom might have 30 footcandles yet the seeing conditions be worse for the eyes of the children than in another classroom having only 10 footcandles. . . .
3. *Efforts To Get More Daylight into the Classroom* . . . (1) protruding the classroom away from the corridor and placing windows on two adjacent sides at the traditional levels; (2) lowering the roof of the corridor and placing clerestory windows in the inside walls of the classroom above the corridor roof. These windows are in addition to the regularly placed windows in the outside wall of the classroom. This method can be used only in a one-story structure.
4. *A slight tendency toward depending almost wholly upon artificial lighting as the main light source and using the windows just to see out.*

There are other methods to create bilateral and trilateral lighting that Essex has not mentioned in his summary. The use of glass brick to create indirect diffused lighting is being attempted in some schools (21:25). Fluorescent light has been used extensively in schools. There have been cases in which it has not been entirely satisfactory. Some schools are using photoelectric cells to turn artificial lights on and off as the natural light varies. Any type of lighting must be measured according to the ability of the students to study and perform the necessary activities within the classroom with a minimum of eyestrain.

Chalkboards

The highest grade of slate or glass has been generally found to be satisfactory for the chalkboard. Engelhardt and others (15:102) state that for high schools the chalkboard trough should be 32 inches to 36 inches from the floor. The amount of linear chalkboard space is a problem that seems to have no definite answer. It will depend on the amount of space desired by the teachers who will use a particular room. Brackley (7), after a survey of literature to determine the needs of a modern mathematics classroom, concluded that 25 to 45 linear feet should be ample in most instances to accommodate any teacher.

Squared chalkboards are becoming a necessary part of mathematics teaching. They usually occupy one section 36 inches to 40 inches wide on the corridor wall toward the front of the room. However, there appears to be no valid reason why they should not be located on the front wall. It is sufficient to have the section ruled and outlined in pale green or yellow paint with heavier lines for every fifth or tenth space. An alternative to squared chalkboards is the use of chalkboard stencils. This device is convenient where space is limited or additional squared areas are needed.

Circular sections which may be rotated or clamped in a fixed position have been slow in finding their way into the mathematics classroom. However, they have enough uses to warrant broader consideration. Almost all mathematics courses require that the teacher, at some time or another, demonstrate concepts related to the circle. The circumference of this device painted with white enamel could serve as a permanent circle which would save countless minutes that could better be used for other purposes. The rotating feature of the circular section can be used for drill work. Every teacher has seen students learn the concepts behind a figure in a fixed position, but as soon as the figure is displayed in a different position, a number of students become completely confused. The circular section permits a teacher to explain from one position of a figure and merely to rotate it to get a variety of views of exactly the same figure. It seems that a circular section with a diameter of approximately 30 to 36 inches would serve this purpose quite adequately. (Some teachers feel that the features just described could be included in a portable device, thus permitting the valuable wall space to be used for other purposes.)

The most satisfactory chalk and eraser trough has an open wire screen with ¼ inch to ⅜ inch mesh above the trough. This arrangement permits use of a vacuum cleaner in the trough without removing chalk and erasers. The inside of the trough should be 2¾ inches wide with a 2-inch space between screen and trough.

Miscellaneous Features

The advent of various type projectors as aids to classroom learning make it imperative that electrical outlets become a permanent part of every mathematics classroom. An outlet at the front of the room and another in the rear of the room would probably take care of normal needs. However, if the classroom is to serve as a workroom or a mathematics laboratory, other outlets should be accessible to work benches.

Clocks, public address systems, and thermostats are items that do not specifically apply to a mathematics teacher in classroom planning, but in many instances will be present in the classroom because of over-all school planning. In this regard, teachers are often asked to express opinions as to whether they feel clocks should be present in each classroom and whether the public address system should permit an administrator to listen in on a class recitation. Most teachers are in favor of clocks, but are against the "listening in" privilege; however, it is only fair to mention that there are arguments both pro and con. There are educators who feel clocks should no longer be located on walls, but rather should be an integral part of the desk where they can be seen only by the teacher. Their argument is that clocks are a detracting influence to students. Conclusive decisions should be made only after much consideration and discussion.

III. Furnishings for the Mathematics Classroom

Storage Facilities

Adequate storage is a desire close to every teacher's heart. A major criticism of the older type classrooms and many of the newer ones is that there is not enough storage space available. In many instances this lack of storage has been a major deterrent to assigning project work. Teachers complain that there is no place to keep project work or the supplies necessary to do such work; consequently, they avoid it completely. In other words, the lack of storage space actually hinders the advancement of an accepted, basic idea in education—"learning by doing."

Storage space may be classified in the following categories: chart cases, open shelves, closed shelves, magazine rack, drawers, and teacher's locker. Although facilities for each of the above categories may be purchased separately, the trend in new school buildings is for built-in equipment. The amount of storage space advisable for any particular mathematics room will vary according to the activities that will take place in the room, limitations due to the layout of other facilities, and distance between parallel partitions. Consequently recommendations made in succeeding paragraphs are, of necessity, general in nature and should be interpreted accordingly.

With regard to chart cases, Engelhardt and others (15:102) say:

> The space below blackboards may be used advantageously by installing chart cases. These cases may be 2 feet to 3 feet wide and the depth need not exceed 6" to 8". They should be as high as possible. The doors should be hinged on the bottom and equipped with a heavy wire spring bumper to hold charts tight against the door. It is advisable to install air vents in the cases to prevent the air pressure caused by closing one door from opening an adjacent door.

The authors have presented some excellent suggestions for the storage of charts, but this writer doubts that space as detailed as that described is necessary in a mathematics classroom. One or two large shallow drawers would be more suitable to hold them. Furthermore, some writers feel that, if possible, the space under the chalkboard should be covered with tile and avoided completely as a storage area.

The reason for this opinion is that, with students working at the chalkboards, it will not be too long before the chart case doors become marred and unsightly because of careless feet. Furthermore, if the space under the chalkboards is covered with colorful tile, its appearance would tend to break up the monotony of the other necessary and desirable storage facilities.

Open and closed shelves may be located in available areas on the corridor wall, the rear wall, or the window wall. The closed shelves should be used primarily to store unsightly materials like glue, tacks,

cardboard, glass, string, plastic, and papers. Open shelves are necessary to store books, supplementary texts, and pupil-made devices and projects. The shelves should be placed a minimum of one foot apart, but, if possible, should be adjustable to accommodate various sized objects. A length of 3 to 4 feet and depth of 8 to 12 inches should provide for every need. The number of each type shelf is, indeed, a variable factor, but four to twelve of each kind seem to be safe limits. Summarizing the content of this paragraph, it seems that there should be a minimum of eight open and eight closed shelves, each 3 feet by 1 foot by 8 inches. However, it is possible that a particular classroom might have eight open and twelve closed shelves, each 4 feet long and 1 foot deep with sliding doors. Teachers should keep in mind that open shelves tend to be notorious dust collectors.

The fine articles of such magazines as *The Mathematics Teacher, School Science and Mathematics, Popular Science,* and *Scientific American* and the interesting articles pertaining to mathematics which appear in a variety of pamphlets, newspapers, and magazines should be made available to all mathematics students. Provision must be made to store these sources of supplementary material. It is possible to use the open shelves previously described for this purpose, but it would seem much more advisable and practical to use magazine racks. Portable racks may be purchased and hung over the eraser trough in some corner or possibly propped up in some corner of the room where they will not interfere with other activities. However, the best solution seems to be built-in magazine racks, perhaps located under a set of closed shelves on the corridor side of the room. Four tiers of racks extending approximately 3 feet in height and 3 to 4 feet in length would adequately serve the needs of any mathematics classroom. The tiers may lean toward the room or toward the partition, but in either case the slope should be approximately 2 to 1. The tiers, in turn, should be subdivided every 10 to 12 inches. The majority of the teachers approached on the subject of magazine racks felt the racks should not be enclosed, but instead should be bounded by wooden strips so that most of the front magazine is exposed. The racks, they explained, would be less susceptible to dust and furthermore would be much easier to keep clean.

Drawer space beyond that available in the teacher's desk is a necessity in every mathematics classroom. Additional space may be available in demonstration tables or work tables, but these will not necessarily be present in all classrooms. In one recently erected high school a part of the teacher's closet was used for drawer space. Originally the closet was 3½ feet by 2½ feet by 7⅓ feet, but after careful planning it was decided to use the left side of the closet for four drawers with face dimensions of 1 foot 9 inches by 10 inches and a front to back length of 2½ feet. Above the drawers four more adjustable shelves were installed. This plan still left a space of 1¾ feet by 2½ feet by 7⅓

feet available as a teacher's locker with a clothes pole and shelf above.

If a school is departmentalized, it is a good idea to have a separate room for book storage. This room should have floor-to-ceiling fixed shelves on two walls with 1½ feet to 2 feet between shelves. A depth of from 12 to 18 inches for each shelf would be advisable in a room of this type. This room may vary in size anywhere from 100 to 200 square feet, depending on the size of the department it will serve.

Display Boards

A maximum amount of bulletin-board space is usually advantageous in a mathematics classroom. Cork is usually the preferred material as it does not show tack holes and may be painted in any color. After painting, holes caused by tacks will show, but annual painting will prevent any unsightly conditions. Corkboard walls or panels above chalkboards are very desirable. Pegboard also has many uses in displaying materials.

Bedford (3:200) believes a built-in multiplex fixture provides the greatest economy of space and is unobtrusive. Ten leaves, 3 by 2 feet, provide 120 square feet of display, or as much as a bulletin board 4 feet wide and 30 feet long. Although this ingenious piece of equipment seems to be dimensionally sound, it still cannot exhibit more than two 3-by-2-foot leaves at one time.

This writer was unable to find any literature which recommended specific dimensions for wall bulletin boards. Brackley (7:117) recommends as much space as possible. Corridor and rear walls are the favorite locations, and one author (3:200) suggests that a bulletin board in the corridor could be used to popularize mathematics and serve in a guidance capacity. An area of approximately 12 to 15 square feet seems adequate for the latter purpose. In the classroom an area approximating 18 to 24 square feet in a single or double section should be ample to serve most needs. Again, the problem of amount is an individual one with schools and will depend on the use that such equipment will receive in any mathematics classroom.

It should be mentioned here that a company[1] has devised a multipurpose reversible fixture, one side of which is black board and the other, cork. The device is extremely flexible and can be used for many purposes other than chalkboard and bulletin board. It comes in 3 foot by 3 foot panels, and any number of panels may be purchased. However, the fixture is comparatively new and, as such, still seems to be unproven by experience. At present, its major disadvantage is the high cost of materials and installation.

Exhibit Cases

Mathematics rooms need more space for displaying pupil work; good teaching includes granting proper credit for achievement. The

[1] Austral Sales Corporation, 101 Park Avenue, New York, New York.

writer has already discussed one phase of classroom display in the section on bulletin-board space. Another, and equally important, phase of classroom display is the glass-enclosed exhibit space. This space should be used exclusively for exhibition, and should not become just another area for storage of texts and miscellaneous equipment. The exhibit case (25) is another means to "dramatize the role of mathematics in modern life." It should show largely the actual materials of daily class instruction, and in this connection should use the instruments and gadgets on hand for classroom instruction.

The exhibit case should occupy an area of approximately 12 to 16 square feet on the corridor side of the classroom. Holmes (23) advocates adjustable plate-glass shelves with concealed electrical lighting. Although the plate-glass shelves and lighting features are desirable, they hardly seem essential to the average classroom. If the shelves are fixed, they should be a minimum of one foot apart. The depth of the shelves in an exhibit case may vary from 8 to 12 inches with the larger limit being more desirable.

In addition to the classroom exhibit case, Bedford (3) advocates a similar space in the corridor "to popularize mathematics throughout the school." A space of this type is particularly desirable for a school where mathematics is departmentalized. This space should be kept locked in order to prevent tampering.

Another possibility with regard to exhibit cases is to have classroom cases facing out into the corridor. This plan has been used successfully in many of the newer elementary schools, but seems to be slow in finding its way into the high school.

Shades and Curtains

The authors of *Planning Secondary School Buildings* (15:109) say:

> Every room should be equipped with opaque shades operating on tracks or in grooves and fitting tightly at top and bottom to prevent light leaks. The advent of motion pictures in the classroom has emphasized the importance of good shade construction. The use of heavy drapes or curtains operating on a track may satisfy the need but prevents control of horizontal light. A combination of translucent shades and curtains provides the most satisfactory arrangement. In this case the shades should operate up and down from the center of the window.

The rooms in many of the recently built schools are equipped with shades, either the conventional single roll or the double roll type. The teachers seem to feel the arrangement is suitable, but all agree that the addition of curtains or drapes would be even better. Besides having a practical value curtains or drapes add warmth to a classroom to the same extent as in the living room of a home.

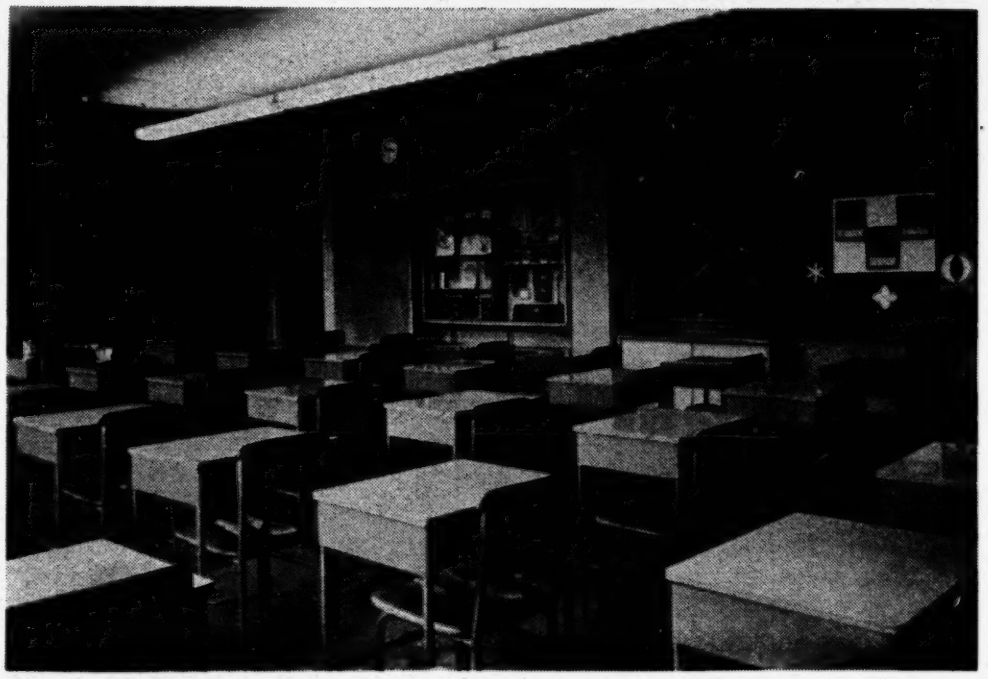
Furniture Needs and Selection

There seems to be a definite trend away from the conventional fixed desks and chairs to movable desks and chairs, or tables and chairs. In this respect Schorling (37) says:

. . . it is suggested that whenever possible the traditional nailed-to-the-floor desks be replaced by flat-top work tables preferably in two sizes, say one group 30 inches high and another 27½ inches with comfortable chairs to match. Flexible furniture contributes not only to informality, but also to a variety of procedure and the assignment of differentiated tasks.

Bedford (3) in his diagram[2] of a mathematics classroom has included six work tables, three along the window-side of the room and two larger ones in the rear of the room. In addition, the room contains 24 movable desks and chairs. The general purpose behind this arrangement is that work-table space is arranged for half the pupils at one time. The work tables provide space for work in groups, for using calculation machines or for performing experiments.

Some authorities advocate that every mathematics classroom have at least one, possibly two, reading tables in one corner of the room. These tables would make available supplementary reading materials that the children can use in connection with the problems they are working on, or for leisure reading.



A demonstration table with water, sink, electricity, and supports for experiments in mechanics is a necessary fixture in every mathematics classroom, according to Bedford (3). He believes that a table of this type would permit experimentation preceding generalization, and further would prevent the teacher's desk from becoming a "catchall."

[2] See Chapter VII.

Syer (42) goes even farther with his suggestions for a mathematics laboratory. His room contains a sink and table for plaster-of-paris work, a table for wood and metal work, a physics table with gas and electrical fixtures, and two drafting tables.

Obviously, if a room were to contain all the furniture described in preceding paragraphs, little room would be left for anything else. Consequently, it seems feasible to say that there is a need for two types of rooms in the modern mathematics program—the conventional type room and a specialized room which might be called a mathematics laboratory or a mathematics workroom. The conventional type room should contain a teacher's desk and chair preferably located in a corner, a demonstration table, approximately 25 movable student tables and chairs, and perhaps an extra table and four chairs which could double as a work table and reading table. The writer feels that book storage facilities should not be available on the tables, but the chairs should have horizontal racks under the seat to hold the occupant's books. This type of arrangement will make it easier to maintain neat and orderly student stations. The demonstration table in this room would not have water, sink, and electricity because the cost of installing these services would seem prohibitive in comparison to the amount of use they would get. On the other hand, the mathematics workroom (one should be enough) should contain two to three work tables, either round or rectangular, a sink and water, two work benches for plaster-of-paris and metal work, two dafting tables, and a physics table with fixtures. The latter item should require a lot of thought, however, because a physics table is an item of considerable expense selling for approximately $1000. If it is not going to be used enough, it hardly seems a worthwhile investment. Furthermore, there should be enough correlation between the science and mathematics departments to make the equipment of one available to the other, whenever necessary. At any rate, the problem is one that has to be discussed and decided upon by individual departments. The problem of water and a sink in every classroom was a matter discussed quite thoroughly by this writer and a group of administrators. It was brought out that pipe lines would have to be extended a considerable distance in order to make this accommodation. The additional cost was weighed against the amount of use the sinks would get and it was agreed that the investment could not be justified. However, it was further agreed that water and a sink could easily be supplied for one room, the workroom, because the room could be so situated that the length of pipes necessary would be negligible.

A teacher's desk and chair, of course, are essential pieces of classroom furniture. In this regard the trend seems to be toward modern furniture in light colors. Ample drawer space is still of primary importance. Because the teacher's desk is losing its use as a "catchall"

for demonstration materials, books, and the like, many schools are locating the teacher's desk and chair in a corner of the room away from the central activities of the classroom. This new location tends to give the desk a limited amount of privacy. Next to the teacher's desk there should be a two-drawer file for the teacher's personal use. It is possible that a third smaller drawer for filing 4" by 6" cards might prove very useful. Some administrators feel, however, that it is less expensive and just as practical to provide the file space in the teacher's desk.

The problem of furniture selection is one of utmost importance. Once furniture has been ordered, there is no turning back; good or bad, it becomes a permanent part of the classroom. Fortunately, however, most school furniture companies are happy to set up exhibitions displaying the various items in their catalogues. In this way an interested teacher is given ample opportunity to make comparisons and thus make intelligent and practical decisions.

With regard to design and dimension of desks (21:44-48), Boyd says:

> . . . . In reading, writing, drawing, and other two-dimensional tasks, the working surface should tilt 20° out of the horizontal, and should be adjustable for height so that the inner edge will just meet the child's elbows as he leans forward to the balanced posture required by the close task he is performing. In modeling, construction, and other three-dimensional activities, the child needs a horizontal working surface. The height of this surface is determined somewhat by the size of the three-dimensional task in which the child is engaged, but in most such activities, at which the child is seated, the height of the working surface should be approximately the same as the child's hand height in his balanced position for plane surface tasks.

Boyd further believes that chairs should either be adjustable for height, or be of proper height for both a balanced pelvis and for minimum compression or restriction of soft tissues. Fixed-height chairs, he warns, should be selected keeping in mind the fact that it is much better for the child to grow out of a fitted size furnished him than to be forced to grow into one of a height initially too large for him.

Wood surfaces should be of light woods, and the finishes should be clear, free of opaque pigments which obscure the wood grain. The finishes should give the wood a slightly warm or "orange" appearance. Surfaces other than wood are making an appearance on the market; one of the most popular seeems to be the plastic top desk. It is advertised as practically mar-proof, acid resistant, waterproof, and easily cleaned. Custodians in schools where this type desk is used are inclined to substantiate these claims.

IV. Equipment and Teaching Aids for the Mathematics Classroom

Equipment

The following pages contain a comprehensive list of mathematical equipment and materials with approximate costs and sources wherever they could be logically included. It is hardly expected that one classroom will have all of this variety of equipment, but it is hoped that the reader may use these pages as a master list from which individual needs may be satisfied. Prices used are those quoted in the literature of the various sources, and represent average quality and price.

In the last column the reader will find the letters E, D, and P. This column expresses the writer's opinion as to whether the various items are essential (E), desirable (D), or possible (P) in a mathematics classroom. Decisions are based solely upon the importance of the equipment and materials to the teaching of mathematics.

Some of the items of equipment listed in this section will be available locally or through local channels. The companies listed below are among those from whom the more specialized items can be obtained.

1. General school equipment and supplies
   - Milton Bradley Company, Springfield, Massachusetts
2. Instruments, laboratory equipment, special tools, etc.
   - Central Scientific Company, 1700 Irving Park Road, Chicago 13, Illinois
   - Laboratory Specialties, Inc., 144 South Wabash St., Wabash, Indiana
   - W. M. Welch Manufacturing Company, 1515 Sedgwick Street, Chicago 10, Illinois
   - Yoder Instruments Company, East Palestine, Ohio
3. Drawing equipment, slide rules, etc.
   - Companies listed in Group 2
   - Eugene Dietzgen Company, 954 Fullerton, Chicago, Illinois
   - Frederick Post Company, Box 803, Chicago 90, Illinois
   - Engineering Instruments, Inc., 50 Smith Street, Peru, Indiana
   - Keuffel and Esser Company, Adams and Third Streets, Hoboken, New Jersey
   - Pickett and Eckel, Inc., 5 South Wabash Avenue, Chicago 3, Illinois
4. Models
   - Companies listed in Group 2
   - W. R. Benjamin Company, Granite City, Illinois
   - Ideal School Supply Company, 8312 S. Birkhoff Avenue, Chicago 20, Illinois
   - Vis-X Company, 4870 Eagle Rock Blvd., Los Angeles 41, California
5. Globes, maps, charts
   - Denoyer-Geppert Company, 5235 Ravenswood Avenue, Chicago 40, Illinois
   - A. J. Nystrom and Company, 3333 Elston Avenue, Chicago 18, Illinois
   - Rand-McNally and Company, 536 Clark Street, Chicago 5, Illinois
6. Visual aid equipment
   - Keystone View Company, Meadville, Pennsylvania
   - Society for Visual Education, Inc., 1345 West Diversey Parkway, Chicago 14, Illinois

General equipment

Item	Cost	Importance		
Duplicator	$208.00	E		
Kaleidoscope	.50			P
Opaque projector	200.00	E		
Motion picture camera	125.00	E		
Motion picture projector	290.00	E		
Motion picture screen	24.95	E		
Pencil sharpener	2.50	E		
Projection lantern (300 watt)	86.75	E		
Radio	30.00			P
Slides (2″ by 2″, 100 per package)	1.50	E		
Stereographs, 50 views	15.00		D	
Typewriter	160.00	E		

Chalkboard equipment

Item	Cost	Importance		
Compass, wooden	$ 1.20	E		
Demonstration protractor	2.90		D	
Demonstration slide rule, 4′	10.50		D	
Gravity protractor	4.00	E		
Liner	.45			P
Meter stick, metric and inches	1.75	E		
Slated globe, 12″	20.00	E		
Stencil graph chart	12.45			P
Triangle, 30°–60°	2.40		D	
Triangle, 45°–90°	2.40		D	
T-square, large	2.40		D	

Instruments

Item	Cost	Importance		
Abacus, Chinese type	$ 6.50		D	
Alidade	6.00		D	
Altimeter, pocket type	20.65			P
Angle mirror	3.50		D	
Arrows 14″, plain	2.70			P
Azimuth computor	8.75			P
Balances and weights	25.00		D	
Calculating machine	190.00		D	
Calipers (vernier)	5.50		D	
Decimalized Tape, 100′	6.50	E		
Drawing boards, 20″ by 26″	2.85		D	
Drawing sets (six instruments)	11.80		D	
French curves, set of eight	4.00			P
Gear sets	13.75			P
Hand levels	10.00		D	
Hypsometer	6.00		D	
Inclined plane with care and pan	11.75			P

Item	Cost	Importance	
Jacobs staff	$4.00	D	
Law of lever set	9.50		P
Lens set	13.50		P
Leveling rod and target	9.00	D	
Magnetic needle compass	1.50		P
Magnetic set	7.25		P
Micrometer screw	5.75	D	
Pantograph (21″ bars)	2.50	E	
Parallel rulers (14″)	1.50	D	
Pelorus	4.75		P
Plane table	20.00	D	
Planimeter	24.00	D	
Plumb bob (steel)	.65	E	
Proportional dividers	15.00	D	
Protractor, circular	1.50	E	
Ranging poles	4.00	D	
Scales, architect	1.25	D	
Scales engineer	1.25		P
Seconds pendulum	14.00		P
Sextant	25.00	D	
Circular, slide rule	2.00	D	
Spherometer	7.00		P
Spring scale, 6″	1.95		P
Stop watch	11.25	D	
Student pencil compasses, 5½″ per doz.	1.70	E	
Student protractor ruler, 6″ per doz.	1.50	E	
Student rulers, brass edge, 12″	.20	E	
Student rulers, brass edge, 24″	.40	D	
Student rulers, 12″ plastic per doz.	2.40	E	
Student slide rules	1.00	E	
Student speed-up geometry ruler	1.25	D	
Student triangles, 45°	.30	D	
Student triangles, 30°–60°	.30	D	
Sundials	5.00		P
Surveyor's level	30.00	D	
Transit-level	75.00	E	
T-squares, 24″	.65	D	
Wheel and axel set	2.60		P

Models

Item	Cost	Importance	
Celestial globe	$49.50	D	
Contour globes	40.00		P
Dissected cone	15.00	D	
Dynamic geometry devices (Shacht instruments, Burns Boards, flexible quadrilaterals, etc.)			P
Geometrical surfaces and solids	8.75	E	
Grove's moto-math geometric set	65.00		P
Hamley multi-model set	25.00		P
Inverse squares illustration	5.00		P
Platonic solids	Make from paper		
Hyperboloid, Ellipsoid, Paraboloid	Make from plaster-of-paris or Grove's Set		

Tools[1]

Following is a list of tools with retail price per item and suggested number needed for a group of 15 to 20 persons. The prices quoted are those from local stores and from a mail-order house. Where two prices are given, they represent a minimum and maximum for satisfactory quality.

Quantity	*Item*	*Cost*	*Importance*	
3	Awls, scratch	$ .25	D	
2	C-clamps, 3″, 4″	.35	E	
2	Chest drills, ¼″	1.49– 5.49	D	
1	Chisel, wood ¾″	1.25	D	
1	Chisel, wood ½″	1.15	E	
1	Chisel, wood ¼″	1.05		P
1	Electric soldering iron	.75– 5.75	D	
1	File, 6″	.59	E	
1	Hammer, mechanics	1.55	D	
1	Hammer, claw	2.59	E	
1	Hammer, small claw	.75– 1.89		P
1	Knife, "Exacto"	5.00	D	
1	Knife, linoleum	.50	D	
1	Knife, utility	1.00	E	
1	Paper cutter, 18″	24.00	E	
1	Plane, Jack 9″	3.79– 5.29	D	
3	Pliers, linesman	2.75	D	
2	Pliers, needlenose	1.49	E	
1	Punch, center	.35		P
3	Punch, eyelet	8.00–10.00	D	
1	Punch, paper	5.00	E	
1	Rasp, shoe, half round	.65		P
20	Sand paper (No. 1, 0, 00)	.03	E	
1	Saw, cheese	.60		P
2	Saw, coping	.69– 1.29	E	
1	Saw, crosscut	4.29	D	
1	Saw, rip	4.49	D	
1	Screw driver, ⅛″	.35	E	
1	Screw driver, ¼″	.98	D	
1	Screw driver, larger	1.20	D	
2	Shears, paper, large	4.25		P
2	Shears, paper, medium	3.50	E	
2	Shears, paper, small	1.00	D	
1	Shears, tin, medium	1.98	E	
1	Shears, tin, small	1.49		P
1	Stapler	6.00	E	
1	Square	79.– 1.39	E	

[1] This section and the next are adapted from a paper written by Richard C. Davis, Cornelia H. Van Doorn, and Wilbur R. Powers for a summer class in "The Mathematics Laboratory" under the direction of Dr. Henry W. Syer at the University of Michigan, Ann Arbor, Michigan, 1951.

Supplies

The following list of supplies may be purchased from bookstores.

Quantity	*Item*	*Cost*	*Importance*		
1	Brush, varnish, 1″	$ .25		D	
1	Brush, No. 2	.10		D	
1	Brush, No. 4	2 for .25	E		
1	Brush, No. 6	.15			P
1 tube	Cement, Duco	.30	E		
1 lb.	Clay, Arton's modeling	.30		D	
1 ball	Cord, heavy	.85	E		
500	Eyelets	1.00		D	
1 jar	Glue, rabbit skin	.75		D	
1	Ink, Higgins India, black, red	.30	E		
1	Mucilage, Le Page's	.10	E		
90	Notebook rings	3 for .10	E		
½ pt.	Paint, poster tempera, black, green	.35			P
1 qt.	Paint, poster, blue, red, yellow	1.65	E		
100 sheets	Paper, graph, 9″ by 12″	2.65	E		
50 sheets	Paper, polar graph	.86	E		
50 sheets	Paper, semi-log. graph	1.52		D	
Pkg.	Paper, black construction, 9″ by 12″	.45	E		
Pkg.	Paper, white construction, 9″ by 12″	.90	E		
	Paper, antique, heavy	per sheet .15		D	
Pkg.	Paper, assorted construction	.45	E		
	Paper, twin-ton	per sheet .15			P
500	Paper, typing	2.00	E		
12	Paper, carbon	.30	E		
	Paper, drafting	per yd. .25	E		
1 roll	Paper, cellophane	.15			P
1 roll	Paper, tissue	.10			P
100	Paper clips	.10	E		
10 sheets	Pebble board	per sheet .30			
100	Pencils, blue	each .10	E		
1 doz.	Pencils, China marking	each .15		D	
100	Pencils, red	each .10	E		
100	Pencils, drawing, 4-H	each .15	E		
100	Pens, lettering, No. 1, 2, 3	12 for .29		D	
50	Pens, writing	3 for .05		D	
25	Pens, holders	each .05		D	
5	Push pins, No. 1	5 for .10		D	
4	Razor blades, single edge	.15		D	
10 boxes	Reinforcements, gummed	per box .10	E		
300	Roundhead paper fasteners, Nos. 2, 3¾″	.35		D	
20 boxes	Rubber bands, assorted	per box .15	E		
12 yd.	Tape, masking	.39	E		
1 roll	Tape, Mystik self stick cloth, ¾″ by 144″, blue, red, white	.25	E		
1 roll	Tape, passe partout-picture binding, 1″ by 12 yds	.25			P
1 roll	Tape, Scotch, black	1.20		D	
120 in.	Tape, Scotch, colored, blue, green, red, yellow	.10			P
1 roll	Tape, Scotch, large roll, ½″, ¾″	2.32	E		
100	Thumb tacks	.20	E		
1 qt.	Turpentine	.69		D	
1 doz.	Yardsticks	each .15	E		

The following list of supplies may be purchased at drug stores.

Quantity	*Item*	*Cost*	*Importance*	
1 gal.	Alcohol, denatured	$2.20	D	
72 doz.	Applicators, hardwood	.50	E	
3 doz.	Glycerin (for soap film experiments)	.35		P
1000	Paper cups	2.71	D	
1000	Soda straws	1.85	D	
300	Toothpicks, round	.10	D	

The following list of supplies may be purchased at five and ten cent stores or dry goods stores.

Quantity	*Item*	*Cost*	*Importance*	
12 cards	Buttons, assorted	$ .10		P
1 yd.	Flannel	.50	D	
8 yds.	Floss, Coats', all colors	2 for .05	D	
	Hairpins	.05		P
1	Mirror, 2″ by 3″	.10	D	
12	Needles, assorted	.05		P
	Safety pins, assorted	.10	D	
1	Thimble, metal	.10	D	
2	Thimbles, plastic	2 for .05	D	
1 Spool	Thread, Clark's, cotton, 30, yellow, blue, dark green, light green, red	.05	E	
1 Spool	Thread, Coats', cotton 8, black	.05	D	
1 Spool	Thread, Hemingway and Bartlett, nylon, blue, brown, green, red	.05		P

The following list of supplies may be purchased from hardware stores.

Quantity	*Item*	*Cost*	*Importance*	
½ pt.	Enamel, all colors	$ .70	D	
1 pt.	Enamel, all colors	1.22	D	
1 qt.	Enamel, all colors	2.25		P
25 ft.	Foil, aluminum	1.00	D	
2	Hinges, small	2 for .10	E	
12	Hooks, L	.15	D	
12	Irons, corner	.70	E	
1 lb.	Nails, 6 penny and up	.12	D	
1 lb.	Nails, 6 penny and down	.13	D	
¼ lb.	Nails, wire ⅞	.15	D	
1 gross	Nuts, hexagonal brass, 6	.90		P
125 ft.	Paper, waxed	.35	D	
1 lb.	Plaster of paris	.05	E	
2	Sandpaper, 8″ by 10″	2 for .05	E	
12	Screws, eye	.15		P
1 gross	Screws, flat head, steel, wood	.76	D	
1 gross	Screws, machine ⅜″ by 6″	.72	D	
1 gross	Screws, machine, ½″ by 6″	.82	D	
1 qt.	Shellac, orange	1.75	E	

	Item	*Cost*	*Importance*
1 qt.	Shellac, white	$1.85	D
12	Sinkers, lead	.10	D
1 lb.	Tacks, carpet	.35	D
1 lb.	Tacks, upholsterers, 9/16″ by 8″	.30	E
1 lb.	Tacks, upholsterers, 8/16″ by 6″	.35	D
12	Washers	.05	D
1 lb.	Wire	.12	D
1 lb.	Wool, steel	.50	P

The following list of supplies may be ordered from the sources indicated.

Quantity	*Item and Source*	*Cost*	*Importance*
1	Keystone Instructor Outfit for Handmade Lantern Slides. Keystone View Company, Meadville, Pa.	$1.85	D
	Contents: 1 Instruction booklet 8 Etched glass 8 Plain glass Slide crayons 6 Carbon paper 6 Cellophane Binding tape		
1 lb.	Bakelite fiber strips, Continental Diamond Fibre Co., Newark, N. J.	1.00	P
1 sq. ft.	Lucite plastic, E. I. duPont de Nemours and Co., Flint, Mich.	2.25	D
	Balsa wood, 3″ by 36″, ¼″ thick, hobby shops	.25 per unit	P
	Balsa wood, 3″ by 36″, ⅛″ thick, hobby shops	.18 per unit	P
	Masonite, 4′ by 8′, ¼″ thick, lumber company	.11 per sq. ft.	D
	Plywood, 4′ by 8′, ¼″ thick, lumber company	.20 per sq. ft.	D
	White pine, lumber company	.42 per sq. ft.	P
	Dowels, 3′ lengths, lumber company	.15 per unit	D
	Tin (not tin plate), hardware store	.20 per sq. ft.	P
	Celluloid or plastic, 20″ by 50″, .030″ thick, book store	5.00 per unit	D

Enrichment Materials

The following is a list of enrichment materials of value for the bulletin boards, in the exhibit cases or shelves, and in the files. Some of the items can be acquired by getting on the mailing list of various publishing houses and industrial firms. Other items in the list are project materials that students can make. Finally, even a few of the items may be termed "collector's items." The extent to which such materials are

found in the mathematics classroom will depend directly on the individual teacher's initiative and ingenuity.

Materials	*Importance*		
Ancient clocks		D	
Ancient surveying instruments		D	
Articles in related fields		D	
Blueprints		D	
Charts made by students	E		
Charts showing use of mathematics in conversation, communications, and industry		D	
Clippings on mathematics	E		
Deeds and abstracts		D	
Deposit slips		D	
Drawings	E		
Gas and electric meter dials		D	
Geometric designs	E		
Graphs	E		
Gunnery charts		D	
Gunter's scales		D	
Historical articles and models		D	
Household measures	E		
Insurance policy forms and rate books		D	
Linkages		D	
Maps		D	
Model work	E		
Money orders		D	
Napier's bones		D	
Occupations in mathematics	E		
Pictures	E		
Posters	E		
Proverbs relating to mathematics		D	
Railroad and bus timetables	E		
Stock and bond certificates		D	
Tally sticks			P
Tax forms	E		
Test materials	E		

Pictures

Sam S. Blanc (6) believes that picture selection should be done with a great deal of thought and with a sound purpose. He offers the following criteria for the proper selection of classroom pictures:

Instructional Characteristics:

1. Relevancy of the picture to the instructional program.
2. Truthfulness of the impression the picture creates in the minds of the pupils.
3. Stimulativeness and emotional impact the picture will have on the pupils.
4. Authenticity and contemporaneousness of the objects or ideas depicted.

Compositional Characteristics:

1. Simplicity and unity of the picture in directing attention to one center of interest.
2. Representation of some common object in the picture to enable pupils to judge relative sizes.

3. Artistic proportions of the picture should be pleasing to the viewer.
4. Coloring in the picture should be attractive and accurate.

Physical Characteristics:

1. Technical quality of focus, balance, and lighting accurate.
2. Spots, blemishes, and glare on the picture not present.
3. Size of the picture suitable to use that will be made in display or individual study.
4. Mounting material substantial and harmonizing with predominant colors in the picture.
5. Surface of picture protected against soiling and wear.

With those thoughts in mind the writer offers the following list of pictures with prices and sources. A few of the following pictures are essential to a well-rounded, progressive mathematics program and all of them would certainly be desirable.

Mural entitled "Tree of Knowledge," color, 21" x 38", 75¢, plus 20¢ for mailing. Order from:

Book Mart
Museum of Science and Industry
Jackson Park
Chicago, Illinois

Excellent reproductions of famous buildings to use in correlating mathematics and architecture. Illustrated catalogue, 25¢. Obtain from:

The Perry Pictures Company
Malden, Massachusetts

Portraits of eminent mathematicians: Portfolio I, $5; Portfolio II, $4; single portraits, 50¢. Other pictorial items available. Obtain from:

Pictorial Mathematics
186th Street and Amsterdam Avenue
New York 33, New York

Set of six posters on the "History of Measurement." Each 16" x 21". Depict the history of common units of measurement. Free. Request from:

Educational Relations Department
Ford Motor Company
3000 Schaefer Road
Dearborn, Michigan

"Signal Corps Posters," a set of 20 posters, each 7" x 10¼", showing applications of mathematics in radio and communications. 40¢ per set. Order from:

National Council of Teachers of Mathematics
1201 Sixteenth Street, N. W.
Washington 6, D. C.

Set of 20 prints entitled "Mathematicians," 50¢. Other prints available on various subjects. All prints measure 5½" x 8". Complete 236-page catalogue available for 50¢. Minimum order 50¢. Sold by:

The University Prints
15 Brattle Street
Harvard Square
Cambridge 38, Massachusetts

Numerous charts and graphs are made available occasionally by publishers of mathematics textbooks, business, and industry. Watch for announcements of these in professional journals, at professional meetings, in lists of free and inexpensive aids.

V. Other Facilities

What Type of Classroom?

The majority of authorities indicate that the best type of classroom for a modern mathematics program is the mathematics laboratory, but there is little agreement as to what a laboratory contains. The mathematics laboratory as described by some writers would be little more than a conventional classroom, but with more equipment and materials and broader use of the laboratory method of teaching. In other cases, however, the room to qualify as a laboratory would have to have a floor area of approximately 1200 square feet and correspondingly more equipment and materials. The latter room, although desirable, seems somewhat impractical for all the mathematics classrooms necessary in a high school because of financial reasons. Such elaborate and expensively equipped rooms would immediately be eliminated from consideration, particularly in smaller towns.

This pamphlet has endeavored to describe and make recommendations for a mathematics classroom that will be more than adequate in every respect for towns of any size, and that can certainly qualify as a mathematics laboratory. Basically, it seems that if a room is thoroughly and intelligently equipped, has ample storage and display space, and is sound in its other physical features, it will qualify as a laboratory not so much because of the equipment and facilities present, but because of the methods employed to utilize them.

It is indeed unfortunate that the laboratory method of teaching mathematics does not enjoy more general popularity, particularly in the East. However, the cause is not a lack of desire as much as a lack of knowledge. This situation should be remedied and some colleges and universities are contributing in the proper direction by offering courses in "The Mathematics Laboratory."

The Mathematics Workroom

Every mathematics department could profit by another room which would be available only for laboratory work. The room need not be extremely large, but should contain two to three work tables with adjustable stools, two drafting tables with board storage space, work benches along the wall, and ample storage for tools, materials, and student projects.

Others Features Desirable to a Mathematics Program

A department office and a storage room seem very desirable to the modern mathematics program. The office is a place for department records, planning, and conferences. In addition, it is an excellent location for typing, mimeographing, and the like. Although the depart-

ment head will most frequently use the office, it should be made available to other members of the department.

The storage room is a natural place to store extra texts and equipment that is not used too frequently. A movable ladder and stock cart would find a lot of use here.

In the corridor a large well-lighted exhibit case will tend to popularize mathematics throughout the school. It should display the best results of the workroom and regular classes as well as the various equipment that is a part of the department. Also, the corridor should have a bulletin board to announce jobs in mathematics and to display clippings of interest to the whole school. One small portion of the bulletin board might be devoted to a challenging "Problem of the Week."

Explanation of the General Summary

The next few pages summarize in detail various room sizes and the physical features of a modern mathematics classroom. The last three columns are coded with the letters E (essential), D (desirable), and P (possible). The three columns indicate, respectively, facts that are essential, desirable, and possible for the particular feature listed to the left. In the event that any reader were to use this summary for classroom planning, the facts listed in the "essential" column would result in a mathematics department functionally satisfactory, but minimum in scope. It is more likely that the reader will make most of his selections from the "essential" column, many from the "desirable" column and a few from the "possible" column. It is in this way that the following summary makes allowance for individual preference and taste.

VI. Summary of Physical Features and Furnishings

	E	D	P
I. In each school			
A. Recitation-Discussion rooms[1]			
1. Total area (square feet)	660	704	770
2. Area (per pupil)	22	23	26
B. Discussion-Activity rooms[1]			
1. Total area (square feet)	704	828	1200
2. Area (per pupil)	23	28	40
C. Auxiliary rooms			
1. Workroom (square feet)	176	230	360
2. Math. office (square feet)	100	100	150
3. Storage room (cubic feet)	125	170	250
D. Other room dimensions			
1. Height (linear feet)	9.5	10.5	12
2. Width (linear feet)	22	25	28
3. Length (linear feet)	30	35	28
II. In every class room	E	D	P
A. Furniture			
1. Student tables	Moveable with rubber inserts	Surface that can be fixed at 0°, 10°, or 20°	Plastic top
2. Student chairs	Moveable with rubber inserts	Adjustable	With storage space under
3. Reading tables	One, plain	Two, plain	With storage space under
4. Demonstration tables	One, plain	With water and sink	With electricity and supports for experiments
5. Teacher's desk and chair	Broad surface with ample drawer space	Space for filing 4″ by 6″ cards	Located in corner of room for privacy
6. File	Two-drawer with lock	Four-drawer with lock	Four-drawer with lock and 4″ by 6″ card drawer
B. Chalkboard features[2]			
1. Plain	25 feet	32 feet	45 feet
2. Squared section	36-inch, outlined in yellow or pale green	Every fifth or tenth space with heavier lines	40 inches
3. Circular section	18-inch painted circle	24-inch painted circle	Circular section which may be rotated or fixed in position
C. Display and exhibition features			
1. Bulletin board	18–24 square feet	1 foot panel above chalkboard	Multiplex display fixtures
2. Exhibit case	12 square feet with 8-inch shelves	16 square feet with 12-inch shelves	Lighted with adjustable shelves

Summary of Physical Features and Furnishings—*(Continued)*

D. Storage facilities			
1. Open shelves	Four shelves, 3′ by 1′ by 8″	Eight shelves 4′ by 1′ by 1′, adjustable	One per student
2. Cupboards	Two, each with four of the above shelves	Three, each with four of the above shelves	Adjustable shelves
3. Magazine rack	Four tiers extending 3 feet in height with 2 to 1 slope, moveable	Sloping outward, built in	Bounded by wooden strips, built in
4. Drawer space	Teacher's desk and two-drawer file	Under demonstration table	Build drawers in part of teacher's closet
5. Teacher's closet	3′ by 2′ by 7′ with hangers, one shelf	With three shelves	Build drawers in part of teacher's closet
E. Shades and curtains	Opaque shades	Combination of translucent shades and curtains	Combination of translucent shades and heavy drapes
F. Floor covering	Hardwood floors	Asphalt or rubber tile	Acid resistant terazzo or plastic absestos
G. Wall and ceiling materials			
1. Walls	Paint over cinder block, nonglossy, 60 per cent light reflecting value	Paint over plastic or plywood	Tile up to bottom of chalkboard with light reflecting value of 30 per cent
2. Ceilings	Plain, plaster with light reflecting value of 75 per cent	Acoustical plaster	Tile
3. Doors	Plain, 36 inches wide	With glass panel	With transom
H. Heating and ventilating system[3]	Any kind that will derive proper thermal environment	Eliminate odors and toxic substances from air	Individual thermostat control in each classroom
I. Lighting	Fluorescent or incandescant to provide 50 foot-candles	75 foot-candles	Clerestory domes on corridor side to get 100 foot-candles
J. Miscellaneous items			
1. Clocks	1	Located on corridor wall	Have no clock or locate one on desk
2. Public address system	One way—from principal to room	Two-way without administration "Listening-in" privilege	With "Listening-in" privilege
3. Electrical outlets	Two, front and rear	Three, inside walls	Four, all walls
K. Equipment and Materials[4]			

[1] Based on 30 pupils per room.
[2] Window wall should be free of chalkboard.
[3] Most common proven satisfactory are open window system with gravity or forced exhaust, unit ventilator, central fan with exposure zoning.
[4] See chapter entitled "Equipment and Teaching Aids for the Mathematics Classroom."

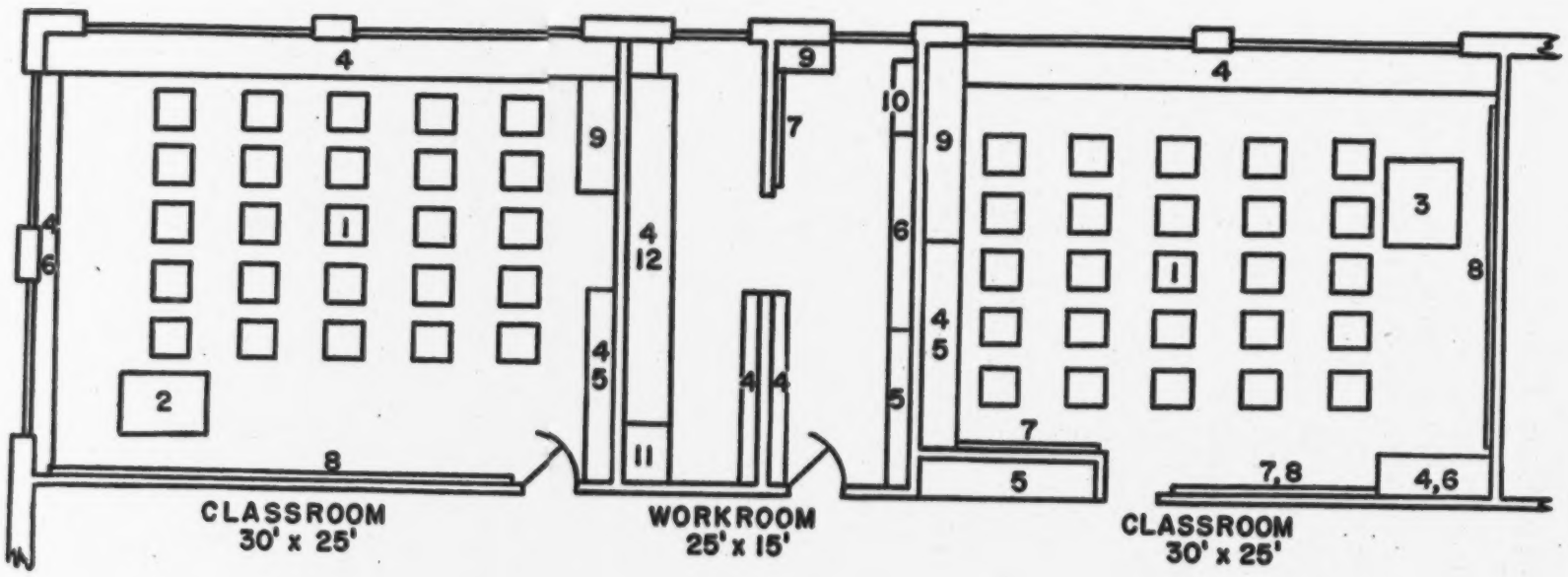
VII. Typical Floor Plans

The floor plans present six detailed layouts for the design of mathematics classrooms. Readers will note that the philosophy involved on page 30 varies somewhat from that of the others. The plan on page 30 utilizes a workroom located between two classrooms, accessible only from the corridor. Those on pages 31 through 37 maintain all the advantages of a workroom, and in addition have made the workroom an integral part of the classroom. A layout similiar to that on page 30 is probably less expensive than the others, but it limits the use of the workroom to individual or small group activities which might create supervision problems. However, a plan of this type may be more feasible for a school whose mathematics staff does not have a philosophy regarding student activity that warrants a layout as detailed and elaborate as those described on pages 31 through 37.

Pages 34-35 and 36-37 show fundamentally the same layouts with variations in the location of certain physical features. Page 35 shows the chalkboard with circular section, graph board, and slide rule located on the front wall. The plan on page 37 shows the same features in reverse order on the inside wall. Page 34 employs a partition projected lengthwise to gain wall space for built-ins and to separate the work area from the library area. The plans on pages 31 and 32 attain the same objective by projecting partitions crosswise. Page 33 also uses the crosswise partition to isolate a work-library area accessible to two groups simultaneously.

Interested readers will find it advantageous to study carefully the content of each floor plan, make comparisons, and then reach individual conclusions pertinent to local philosophy and objectives. The floor plans can be invaluable as guideposts from which sound adaptations can be made according to local need.

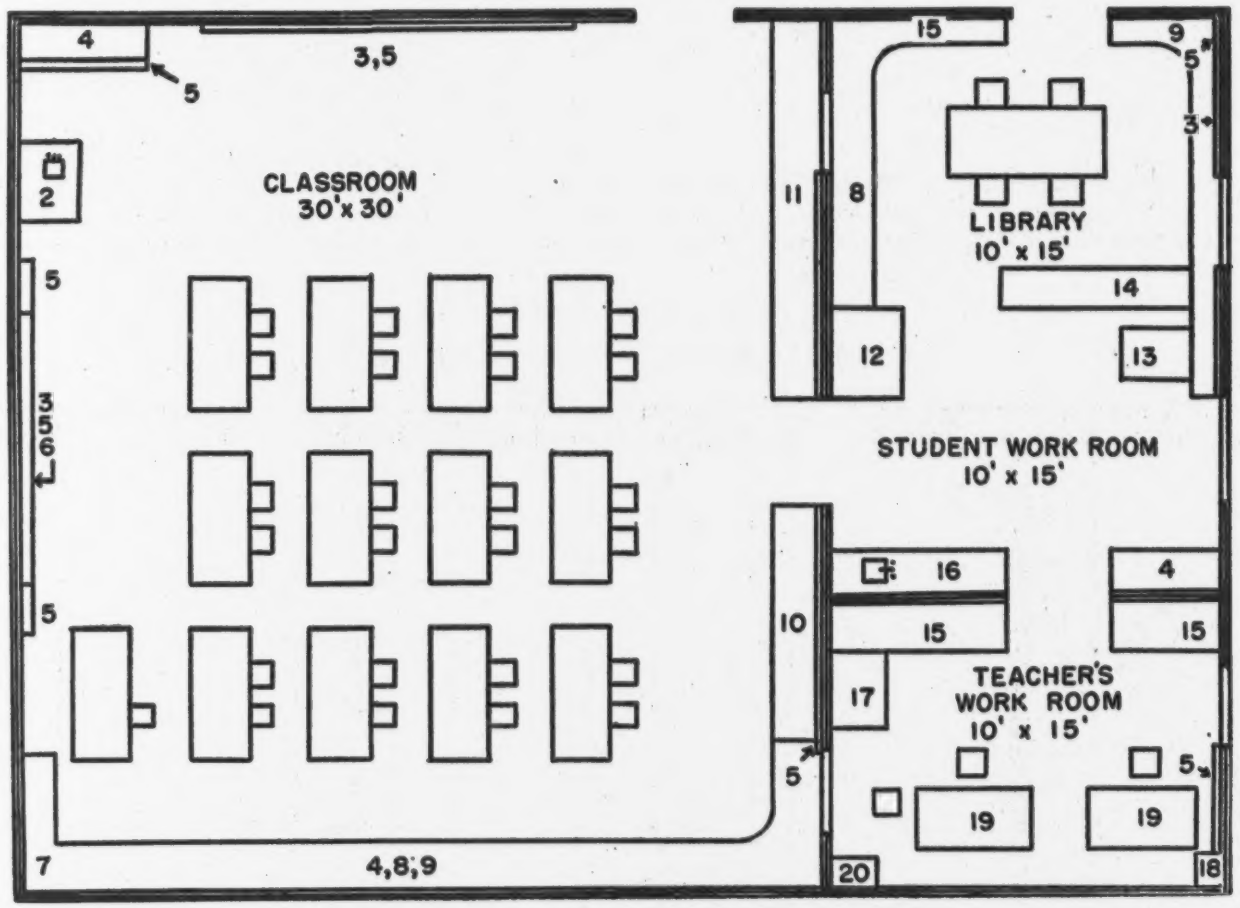
The author wishes to express appreciation to the following persons and organizations for their permission to reproduce the following floor plans: pages 30-31, Donovan A. Johnson and the Laboratory School, University of Minnesota, Minneapolis, Minnesota; pages 32-33, Reinhold Publishing Corporation, 430 Park Avenue, New York 22, New York, publisher of *Planning Secondary School Buildings* by Engelhardt, Englehardt, and Leggett; pages 34-35, Office of School Plant Services, State Department of Education, Atlanta, Georgia; and pages 36-37, The American School Publishing Corporation, 470 Fourth Avenue, New York 16, New York, publisher of *American School and University*.



MATHEMATICS DEPARTMENT

Adapted from Plans for the Laboratory School, University of Minnesota

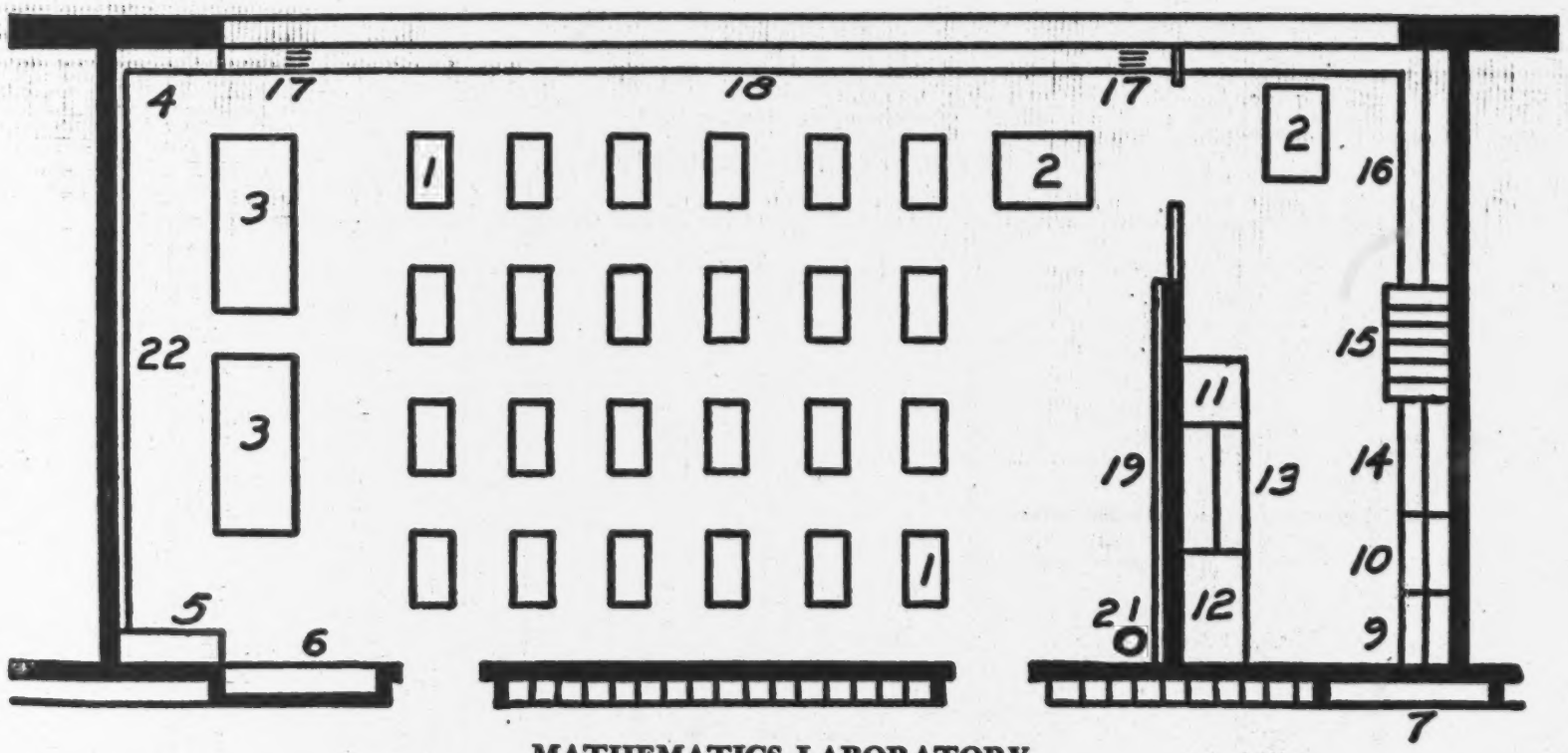
1. Student tables. 2. Demonstration table. 3. Science table, with electricity, water, and gas. 4. Storage. 5. Exhibit cases. 6. Bookcase. 7. Bulletin board. 8. Chalkboard. 9. Cabinet. 10. Magazine rack. 11. Equipment closet. 12. Work counter.



MATHEMATICS DEPARTMENT

By Donovan A. Johnson

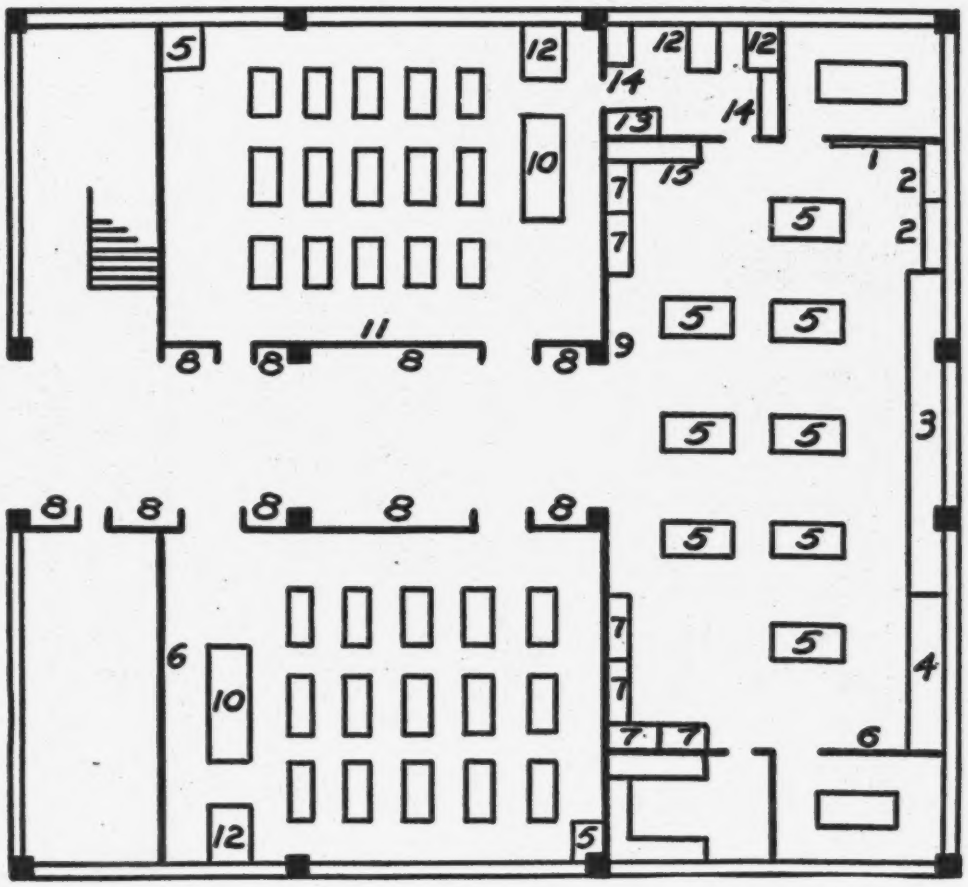
1. Tables for two pupils.
2. Science demonstration table.
3. Chalkboard.
4. Storage cabinet.
5. Bulletin board.
6. Projection screen.
7. Storage drawers.
8. Exhibit shelves and counter.
9. Book shelves.
10. Storage cabinet.
11. Student drawers.
12. Floor to ceiling field equipment storage.
13. Work bench.
14. Cabinet on rubber casters.
15. Film drawers.
16. Work counter and tool storage.
17. Clock closet.
18. Duplication.
19. Teacher's desk.
20. Typewriter and table.



MATHEMATICS LABORATORY

San Francisco Public Schools

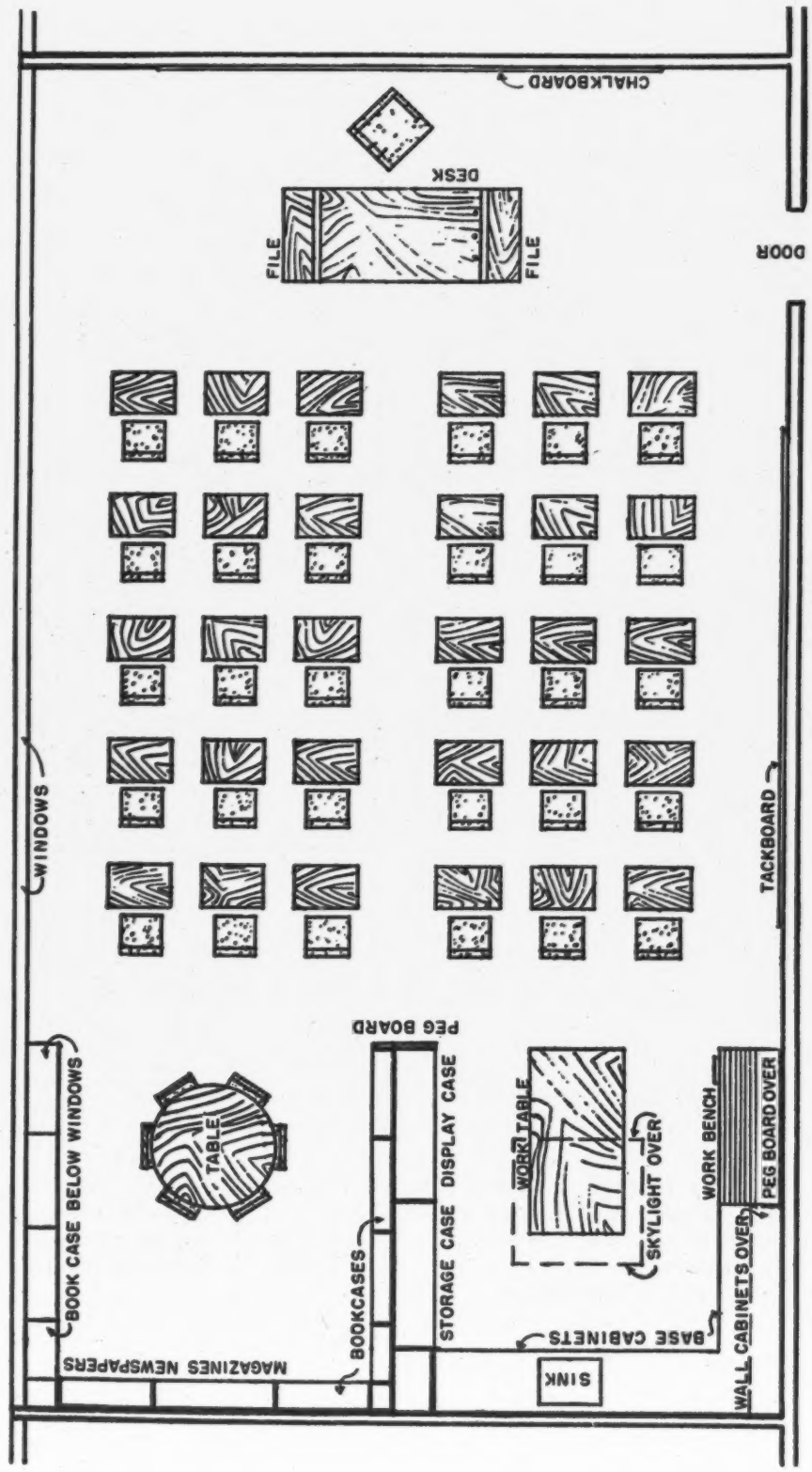
Left: Recitation and Reading Room. Right: Workroom and Model Room. 1. Student's desk. 2. Teacher's desk. 3. Conference table. 4. Newspaper rack. 5. Bookcase. 6. Museum case. 7. Display case. 8. Lockers. 9. Tool case. 10. Model case. 11. Teacher's locker. 12. Chart file. 13. Cabinets. 14. Instrument case. 15. Vertical file. 16. Bookcase. 17. Heating unit. 18. Storage. 19. Chalkboard, cases under. 20. Chalkboard. 21. Spherical chalkboard. 22. Display board.



MATHEMATICS UNIT

By W. K. Harrison and J. A. Fouilhoux, Architects;
N. L. Englehardt, Educational Consultant

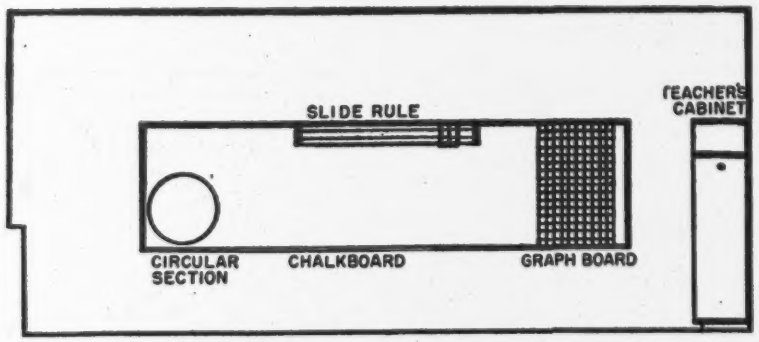
Top: Classroom, Teacher's Office, Conference Room. Center: Corridor, Workshop. Bottom: Classroom, Conference Room (far right). 1. Tool rack. 2. Lathes. 3. Workbench. 4. Solder and glue bench. 5. Work table. 6. Chalkboard. 7. Storage cabinet. 8. Showcase. 9. Bulletin. 10. Demonstration. 11. Display. 12. Teacher's desk. 13. Files. 14. Bookcases. 15. Mimeograph.



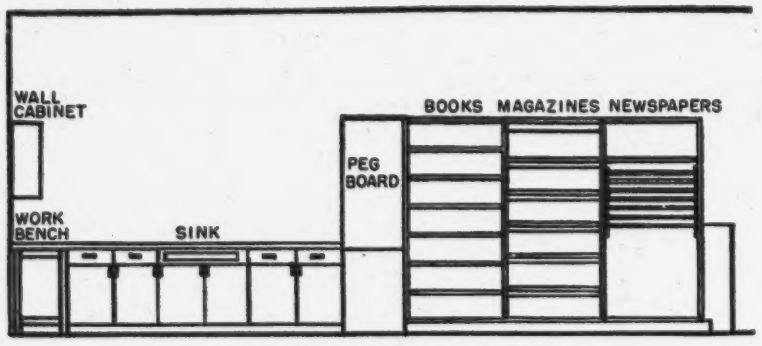
FLOOR PLAN

MATHEMATICS LABORATORY

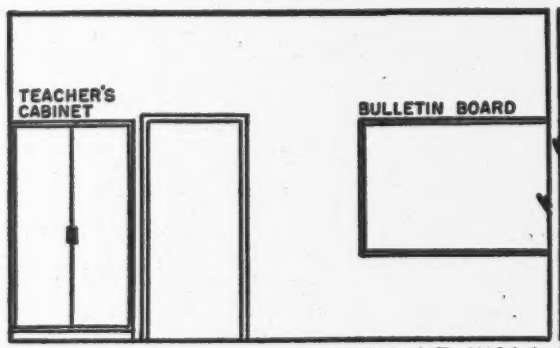
Office of School Plant Services, State Department of Education, Atlanta, Georgia

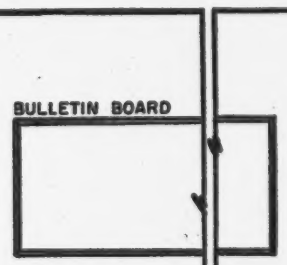


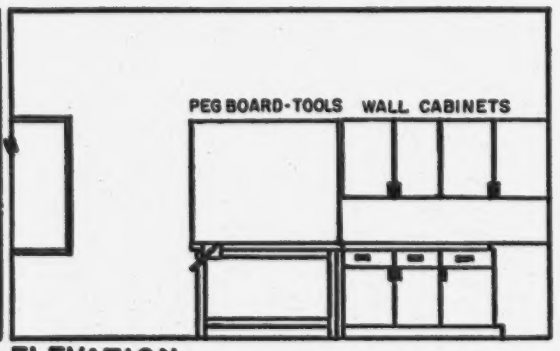
FRONT WALL ELEVATION



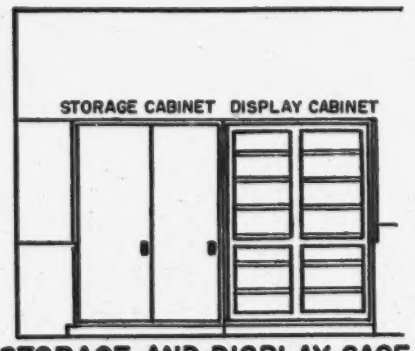
REAR WALL ELEVATION





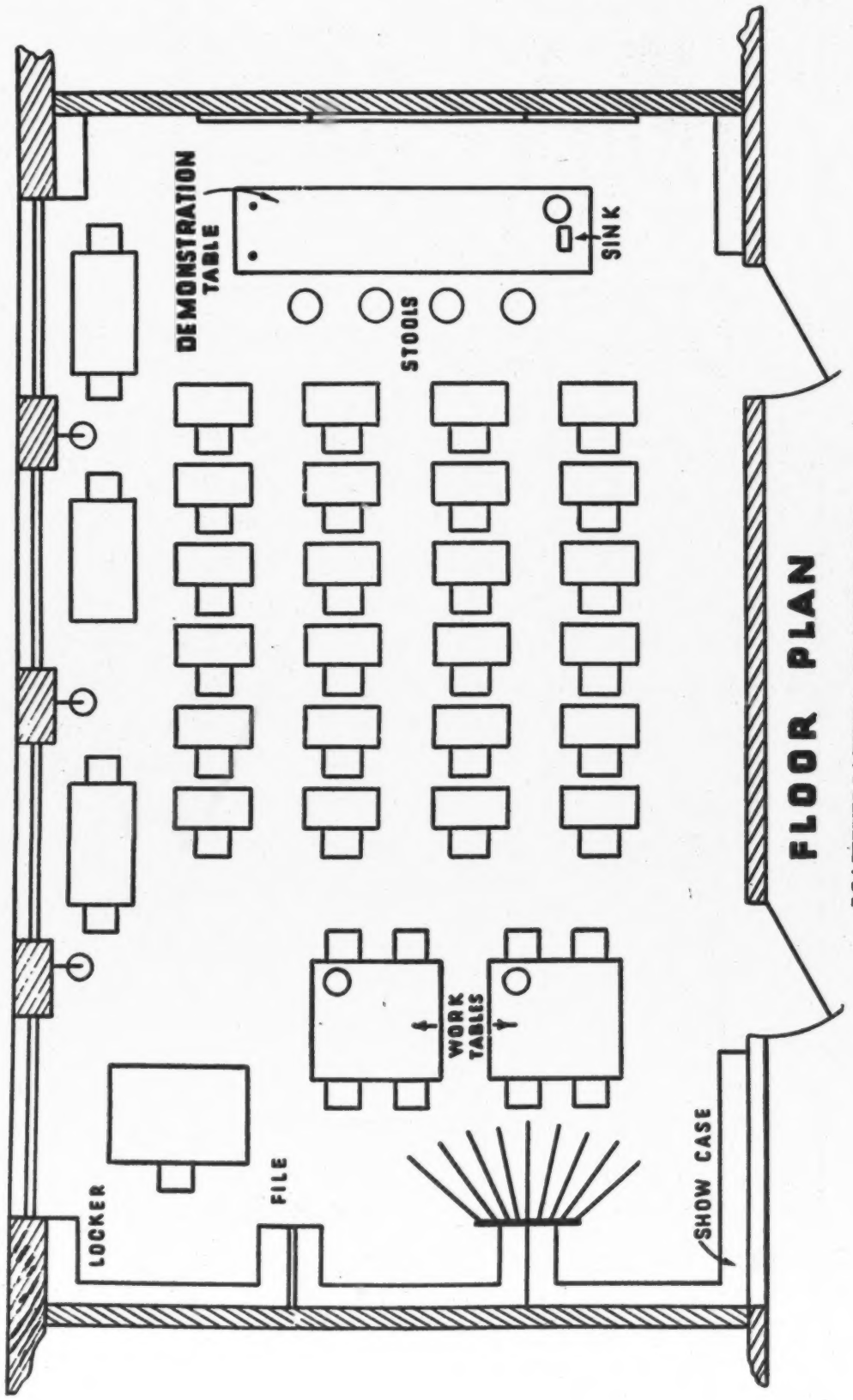


INSIDE WALL ELEVATION



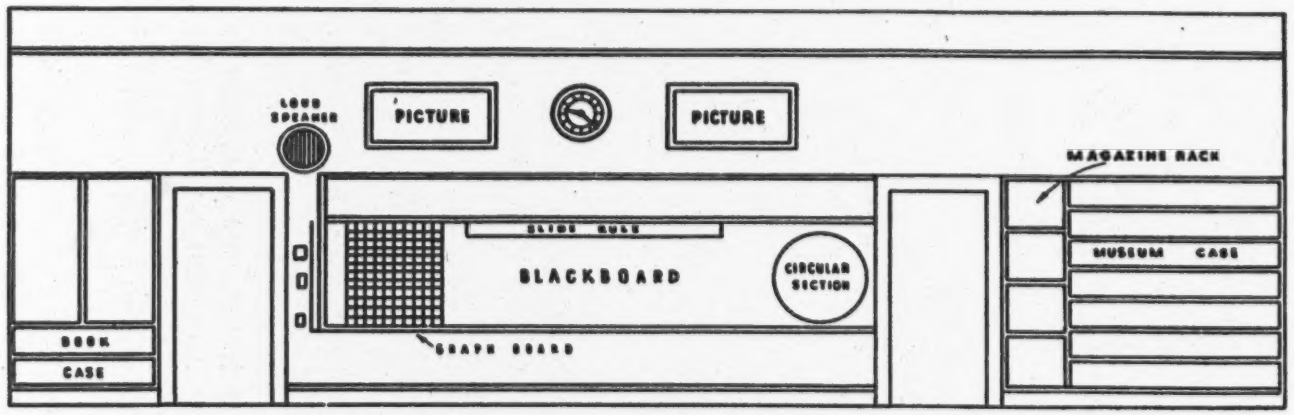
STORAGE AND DISPLAY CASE ELEVATION

Elevations of Mathematics Laboratory

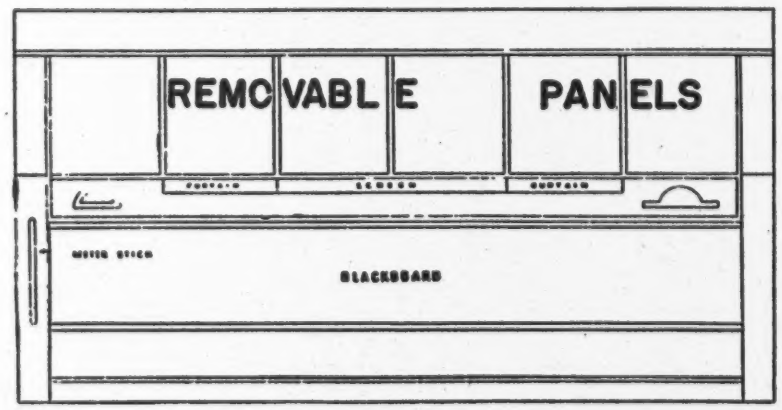


FLOOR PLAN

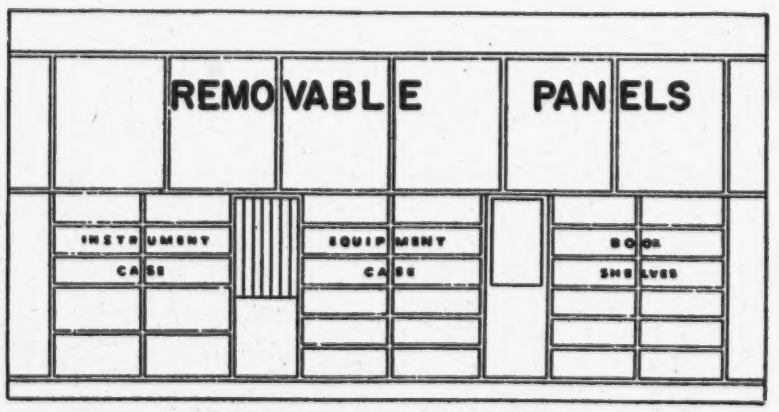
MATHEMATICS CLASSROOM



INSIDE WALL ELEVATION



FRONT WALL ELEVATION



REAR WALL ELEVATION

Elevations of Mathematics Classroom

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